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(71)出願人　000003078
株式会社東芝
神奈川県川崎市幸区堀川町72番地

(72)発明者　上口　裕三
神奈川県川崎市幸区堀川町72　株式会社東芝川崎事業所内

(72)発明者　斉藤　明子
神奈川県川崎市幸区堀川町72　株式会社東芝川崎事業所内

(72)発明者　斉藤　和浩
神奈川県川崎市幸区堀川町72　株式会社東芝川崎事業所内

(74)代理人　弁理士　須山　佐一

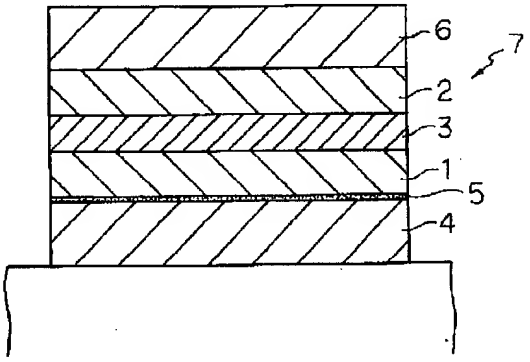
最終頁に続く

(54)【発明の名称】　磁気抵抗効果素子

(57)【要約】

【課題】　スピンバルブ膜を用いたＭＲ素子において、高性能化に悪影響を与えることなく、熱拡散を抑制して熱安定性の向上を図る。

【解決手段】　金属バッファ層４上に形成された第１の磁性層１と第２の磁性層との間に、非磁性中間層３を配置したスピンバルブ膜７を具備する磁気抵抗効果素子において、金属バッファ層４と第１の磁性層１との界面に、酸化物、窒化物、炭化物、ホウ化物、フッ化物等からなる平均厚さが 2nm以下の原子拡散バリヤ層５を設ける。あるいは、磁性下地層と強磁性体層との積層膜からなる第１の磁性層と第２の磁性層との間に、非磁性中間層を配置したスピンバルブ膜を具備する磁気抵抗効果素子において、磁性下地層と強磁性体層との界面に、酸化物、窒化物、炭化物、ホウ化物、フッ化物等からなる平均厚さが 2nm以下の原子拡散バリヤ層を設ける。



【特許請求の範囲】

【請求項１】　金属バッファ層上に形成された第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、

前記金属バッファ層と第１の磁性層との界面に、平均厚さが 2nm以下の原子拡散バリヤ層が設けられていることを特徴とする磁気抵抗効果素子。

【請求項２】　fcc結晶構造を有する金属バッファ層上に形成されたＣｏを含む強磁性体からなる第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、

前記金属バッファ層と第１の磁性層との界面に、酸化物、窒化物、炭化物、ホウ化物およびフッ化物から選ばれる少なくとも 1種を主成分とする原子拡散バリヤ層が設けられていることを特徴とする磁気抵抗効果素子。

【請求項３】　請求項２記載の磁気抵抗効果素子において、

前記原子拡散バリヤ層は、平均厚さが 2nm以下であることを特徴とする磁気抵抗効果素子。

【請求項４】　磁性下地層と強磁性体層との積層膜からなる第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、

前記磁性下地層と強磁性体層との界面に、平均厚さが 2nm以下の原子拡散バリヤ層が設けられていることを特徴とする磁気抵抗効果素子。

【請求項５】　磁性下地層とＣｏを含む強磁性体層との積層膜からなる第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、

前記磁性下地層と強磁性体層との界面に、酸化物、窒化物、炭化物、ホウ化物およびフッ化物から選ばれる少なくとも 1種を主成分とする原子拡散バリヤ層が設けられていることを特徴とする磁気抵抗効果素子。

【請求項６】　請求項５記載の磁気抵抗効果素子において、

前記原子拡散バリヤ層は、平均厚さが 2nm以下であることを特徴とする磁気抵抗効果素子。

【請求項７】　請求項１、請求項２、請求項４または請求項５記載の磁気抵抗効果素子において、

前記原子拡散バリヤ層にはピンホールが形成されていることを特徴とする磁気抵抗効果素子。

【請求項８】　請求項１、請求項２、請求項４または請求項５記載の磁気抵抗効果素子において、

前記原子拡散バリヤ層は、強磁性体または反強磁性体からなることを特徴とする磁気抵抗効果素子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、スピンバルブ膜を用いた磁気抵抗効果素子に関する。

【０００２】

【従来の技術】一般に、磁気記録媒体に記録された情報の読み出しは、コイルを有する再生用磁気ヘッドを記録媒体に対して相対的に移動させ、そのときに発生する電磁誘導でコイルに誘起される電圧を検出する方法によって行われてきた。一方、情報を読み出す場合に、磁気抵抗効果素子（以下、ＭＲ素子）を用いることも知られている(IEEE MAG-7,150(1971) 等参照）。ＭＲ素子を用いた磁気ヘッド（以下、ＭＲヘッドと記す）は、ある種の強磁性体の電気抵抗が外部磁界の強さに応じて変化するという現象を利用したものである。

【０００３】近年、磁気記録媒体の小型・大容量化が進められ、情報読み出し時の再生用磁気ヘッドと磁気記録媒体との相対速度が小さくなってきているため、小さい相対速度であっても大きな出力が取り出せるＭＲヘッドへの期待が高まっている。ここで、ＭＲヘッドの外部磁界を感知して抵抗が変化する部分（以下、ＭＲエレメントと呼ぶ）にはＮｉ－Ｆｅ合金いわゆるパーマロイ系合金が使用されてきた。しかし、パーマロイ系合金は良好な軟磁気特性を有するものでも、磁気抵抗変化率が最大で3%程度であり、小型・大容量化された磁気記録媒体用のＭＲエレメントとしては磁気抵抗変化率が不十分である。このため、ＭＲエレメント材料として、より高感度な磁気抵抗効果を示すものが望まれている。

【０００４】このような要望に対して、Ｆｅ／ＣｒやＣｏ／Ｃｕのように、強磁性金属膜と非磁性金属膜とをある条件で交互に積層して、近接する強磁性金属膜間を反強磁性結合させた多層膜、いわゆる人工格子膜が巨大な磁気抵抗効果を示すことが確認されている。人工格子膜によれば、最大で100%を超える大きな磁気抵抗変化率を示すことが報告されている（Phys.Rev.Lett.,Vol.61,2474(1988)、Phys.Rev.Lett.,Vol.64,2304(1990) 等参照）。しかし、人工格子膜は飽和磁界が高いために、ＭＲエレメントには不向きである。

【０００５】一方、強磁性層／非磁性層／強磁性層のサンドイッチ構造の多層膜で、強磁性層が反強磁性結合しない場合でも、大きな磁気抵抗効果を実現した例が報告されている。すなわち、非磁性層を挟んだ 2つの強磁性層の一方に、交換バイアスを及ぼして磁化を固定しておき、他方の強磁性層を外部磁界（信号磁界等）により磁化反転させる。これにより、非磁性層を挟んで配置された 2つの強磁性層の磁化方向の相対的な角度を変化させることによって、大きな磁気抵抗効果が得られる。このようなタイプの多層膜はスピンバルブ膜と呼ばれている（Phys.Rev.B.,Vol.45,806(1992)、J.Appl.Phys.,Vol.69, 4774(1991) 等参照）。スピンバルブ膜の磁気抵抗変

化率は、人工格子膜に比べると小さいものの、低磁場で磁化を飽和させることができるため、ＭＲエレメントに適している。このようなスピンバルブ膜を用いたＭＲヘッドには、実用上大きな期待が寄せられている。

【０００６】

【発明が解決しようとする課題】ところで、上述したスピンバルブ膜を用いたＭＲ素子においては、強磁性層の結晶配向性等を高めて軟磁気特性を向上させることが重要とされている。例えば強磁性層にＣｏやＣｏ系合金のようなＣｏ系強磁性体を用いたスピンバルブ膜では、アモルファス系材料の上に直接Ｃｏ系強磁性体層を成膜すると結晶配向性が低下して、軟磁気特性が劣化してしまう。そこで、 fcc結晶構造を有する金属膜をバッファ層として形成し、この金属バッファ層上にＣｏ系強磁性体層を成膜することによって、結晶配向性を高めることが検討されている。

【０００７】しかしながら、上記した金属バッファ層としてＮｉＦｅ合金等の軟磁性材料を用いた場合には、Ｃｏ系強磁性体との間で熱拡散が容易に起こり、磁気抵抗効果が劣化してしまう。また、スピンバルブ膜の軟磁気特性を高めて素子感度を向上させるために、外部磁界により磁化反転させる強磁性層を種々の軟磁性材料からなる磁性下地層上に形成することも検討されているが、このような場合にも強磁性層と磁性下地層との間で熱拡散が起こり、磁気抵抗効果が劣化してしまう。

【０００８】スピンバルブ膜を用いたＭＲ素子の製造プロセスにおいては、熱処理が必須であることから、上述した熱拡散による磁気抵抗効果の劣化は重大な問題である。このように、従来のスピンバルブ膜を用いたＭＲ素子は、熱安定性（耐熱性）が低いという問題を有しており、熱拡散の抑制による熱安定性の向上が大きな課題となっている。

【０００９】本発明は、このような課題に対処するためになされたもので、熱拡散を抑制することによって、熱安定性に優れた高性能の磁気抵抗効果素子を提供することを目的としている。

【００１０】

【課題を解決するための手段】本発明における第１の磁気抵抗効果素子は、請求項１に記載したように、金属バッファ層上に形成された第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、前記金属バッファ層と第１の磁性層との界面に、平均厚さが 2nm以下の原子拡散バリヤ層が設けられていることを特徴としている。

【００１１】第１の磁気抵抗効果素子は、さらに請求項２に記載したように、 fcc結晶構造を有する金属バッファ層上に形成されたＣｏを含む強磁性体からなる第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、前記金属バッファ層と第１の磁性層との界面に、酸化物、窒化物、炭化物、ホウ化物およびフッ化物から選ばれる少なくとも 1種を主成分とする原子拡散バリヤ層が設けられていることを特徴としている。

【００１２】また本発明における第２の磁気抵抗効果素子は、請求項４に記載したように、磁性下地層と強磁性体層との積層膜からなる第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、前記磁性下地層と強磁性体層との界面に、平均厚さが 2nm以下の原子拡散バリヤ層が設けられていることを特徴としている。

【００１３】第２の磁気抵抗効果素子は、さらに請求項５に記載したように、磁性下地層とＣｏを含む強磁性体層との積層膜からなる第１の磁性層と、第２の磁性層と、前記第１の磁性層と第２の磁性層との間に配置された非磁性中間層とを有するスピンバルブ膜を具備する磁気抵抗効果素子において、前記磁性下地層と強磁性体層との界面に、酸化物、窒化物、炭化物、ホウ化物およびフッ化物から選ばれる少なくとも 1種を主成分とする原子拡散バリヤ層が設けられていることを特徴としている。

【００１４】第１の磁気抵抗効果素子においては、金属バッファ層と第１の磁性層との界面に、上述したような原子拡散バリヤ層を設けているため、熱処理時における金属バッファ層と第１の磁性層との間の原子相互拡散を良好に抑制することができると共に、金属バッファ層による第１の磁性層の膜質改善効果が得られる。従って、熱処理後に良好な磁気抵抗効果を安定して得ることができ、同時に良好な軟磁気特性を得ることが可能となる。

【００１５】また、第２の磁気抵抗効果素子においては、磁性下地層と強磁性体層との界面に上述したような原子拡散バリヤ層を設けているため、同様に熱処理時における磁性下地層と強磁性体層との間の原子相互拡散を良好に抑制することができる。従って、熱処理後に良好な磁気抵抗効果を安定して得ることが可能となる。

【００１６】

【発明の実施の形態】以下、本発明を実施するための形態について説明する。

【００１７】まず、本発明の第１の磁気抵抗効果素子（ＭＲ素子）を実施するための形態について述べる。

【００１８】図１は、第１のＭＲ素子の一実施形態の要部構成を示す断面図である。同図において、１は第１の磁性層、２は第２の磁性層であり、これら第１および第２の磁性層１、２間には非磁性中間層３が介在されている。これら磁性層１、２間は反強磁性結合しておらず、非結合型の積層膜を構成している。

【００１９】第１および第２の磁性層１、２は、例えばＣｏ単体やＣｏ系磁性合金のようなＣｏを含む強磁性

体、あるいはＮｉＦｅ合金のような強磁性体等により構成されている。これらのうち、Ｃｏを含む強磁性体としては、特にＭＲ変化量に影響を及ぼすバルク効果と界面効果を共に大きくすることができ、これによって大きなＭＲ変化量が得られるＣｏ系磁性合金を用いることが好ましい。

【００２０】上記したようなＣｏ系磁性合金としては、ＣｏにＦｅ、Ｎｉ、Ａｕ、Ａｇ、Ｃｕ、Ｐｄ、Ｐｔ、Ｉｒ、Ｒｈ、Ｒｕ、Ｏｓ、Ｈｆ等の 1種または 2種以上を添加した合金が挙げられる。添加元素量は 5～50原子%とすることが好ましく、さらには 8～20原子% の範囲とすることが望ましい。これは、添加元素量が少なすぎると、バルク効果が十分に増加せず、逆に添加元素量が多すぎると、今度は界面効果が大きく減少するおそれがあるからである。添加元素は大きなＭＲ変化量を得る上で、特にＦｅを用いることが好ましい。

【００２１】また、第１および第２の磁性層１、２の膜厚は、大きなＭＲ変化量が得られ、かつバルクハウゼンノイズの発生を抑制し得る、 1～30nmの範囲とすることが好ましい。

【００２２】上述した磁性層１、２のうち、第１の磁性層１は金属バッファ層４上に形成されており、これによって第１の磁性層１の結晶配向性の向上による膜質改善が図られている。第１の磁性層１に上記したようなＣｏを含む強磁性体を用いる場合、金属バッファ層４としては fcc結晶構造を有する金属材料、例えばＮｉＦｅ合金、ＮｉＦｅＣｏ合金、これら fcc結晶構造の合金にＴｉ、Ｖ、Ｃｒ、Ｍｎ、Ｚｎ、Ｎｂ、Ｍｏ、Ｔｃ、Ｈｆ、Ｔａ、Ｗ、Ｒｅ等の添加元素を添加して高抵抗化した合金等が例示される。これらのうち、ＮｉＦｅ合金やＮｉＦｅＣｏ合金等は、後述する磁性下地層としても機能するものである。また、第１の磁性層１にＮｉＦｅ合金等の強磁性体を用いる場合には、Ｔａ、Ｔｉ、Ｃｒ、Ｃｕ、Ａｕ、Ａｇおよびこれらの合金等を金属バッファ層４として用いることができる。第１の磁性層１は、信号磁界等の外部磁界により磁化反転する磁性層、いわゆるフリー磁性層である。

【００２３】そして、第１の磁性層１と金属バッファ層４との界面には、原子拡散バリヤ層５が形成されており、これによって熱処理時における第１の磁性層１と金属バッファ層４との間の原子の熱拡散を抑制している。すなわち、原子拡散バリヤ層５を形成することによって、熱拡散による磁気抵抗効果の劣化を抑制することが可能となり、ＭＲ素子の熱安定性が向上する。原子拡散バリヤ層５は、熱的に安定で、第１の磁性層１と金属バッファ層４との間の原子相互拡散を抑えることが必要であるが、あまり厚いと金属バッファ層４による膜質改善効果が得られなくなるため、原子の相互拡散抑制効果に悪影響を及ぼさない範囲で薄くすることが望ましい。このため、原子拡散バリヤ層５の厚さは、平均厚さで 2nm以下とされている。ただし、あまり薄すぎると原子拡散バリヤとしての機能が損われるため、平均厚さで 0.5nm以上とすることが好ましい。

【００２４】原子拡散バリヤ層５の構成材料としては、熱的に安定な酸化物、窒化物、炭化物、ホウ化物、フッ化物等を用いることができ、これらは単体として用いる場合に限らず、混合物や複合化合物等の形態で用いてもよい。これらのうち、特に形成が容易でかつ原子の拡散抑制機能に優れる自己酸化膜、表面酸化膜、不動態膜等が好ましく用いられる。これらの化合物からなる原子拡散バリヤ層５は、金属バッファ層４を形成した後に、その表面を一旦大気に晒したり、あるいは酸素、窒素、炭素、ホウ素、フッ素等を含む雰囲気中に晒すことによって形成することができる。また、イオン注入法を用いたり、プラズマに晒す等によっても形成することができる。

【００２５】また、原子拡散バリヤ層５を構成する化合物は、化学量論的に正確な組成でなくてもよく、きれいな結晶格子を組んでいる必要もなく、またアモルファス状態であってもよい。さらに、原子拡散バリヤ層５の形態は、一様に金属バッファ層４の表面を覆っていなければならないものではなく、例えばピンホールが形成された状態、上記した酸化物、窒化物、炭化物、ホウ化物、フッ化物等が島状に存在した状態等、非連続状態で形成されていてもよい。原子の相互拡散抑制効果に悪影響を及ぼさない程度に、ピンホール等があった方がより好ましい。これは膜質改善効果や磁気的結合が低減されるおそれがあるからである。以上の点を考慮すると、ピンホールの平均サイズは互いに隣接するピンホール間の距離と同程度か、それより小さいことが好ましい。

【００２６】一方、第２の磁性層２は、その上に形成されたＩｒＭｎ膜、ＦｅＭｎ膜、ＮｉＯ膜等からなる反強磁性層６、あるいはＣｏＰｔ膜等からなる硬磁性層により、バイアス磁界が付与されて磁化固着されており、いわゆるピン磁性層である。なお、このピン磁性層としての第２の磁性層２は、上記したように強磁性体層の磁化を反強磁性層６等で磁化固着したものに限らず、例えば硬磁性層等を直接使用することもできる。

【００２７】ここで、第１の磁性層１および第２の磁性層２の磁化方向は、ＭＲ素子の線形応答性を向上させる上で、外部磁界が零の状態で例えば直交させておくことが好ましい。このような磁化状態は、例えば以下に示すようなアニール処理を施すことによって得ることができる。すなわち、(1)1kOe 程度の磁場を印加しつつ523K程度の温度で 1時間程度保持した後、(2)そのまま1kOe 程度の磁場中で483K程度の温度まで冷却し、(3)483K程度の温度となったところで磁場の印加方向を90° 回転させて室温まで冷却する。このようなアニール処理（以下、直交アニールと呼ぶ）により、直交させた磁化状態を安定して得ることができる。具体的な磁化方向は、第

１の磁性層１の磁化方向をトラック幅方向とし、第２の磁性層２の磁化方向を第１の磁性層１の磁化方向と直交する媒体対向面に対して垂直な方向とすることか好ましい。

【００２８】また、第１および第２の磁性層１、２に対するアニール処理は、上記した直交アニールに限らず、第１および第２の磁性層１、２の結晶性を向上させるためにも実施される。この場合には、100～400K程度の温度で 1分～10時間程度の条件でアニール処理を行う。

【００２９】上述した磁性層１、２間に配置される非磁性中間層３は、常磁性材料、反磁性材料、反強磁性材料、スピングラス等により構成されるものである。具体的にはＣｕ、Ａｕ、Ａｇ、あるいはこれらと磁性元素とを含む常磁性合金、Ｐｄ、Ｐｔおよびこれらを主成分とする合金等が例示される。ここで、非磁性中間層３の膜厚は 2～ 5nm程度の範囲に設定することが好ましい。非磁性中間層３の膜厚が2nmを超えると抵抗変化感度を十分に得ることができず、また 5nm未満であると磁性層１、２間の交換結合を十分に小さくすることが困難となる。

【００３０】上述した各層によりスピンバルブ積層膜７が構成されており、このようなスピンバルブ積層膜７を具備するＭＲ素子においては、第２の磁性層２は磁化固着されているのに対して、第１の磁性層１は外部磁界によって磁化反転するため、非磁性中間層３を挟んで配置された 2つの磁性層１、２の磁化方向の相対的な角度が変化して磁気抵抗効果が得られる。

【００３１】上記実施形態のＭＲ素子においては、第１の磁性層１と金属バッファ層４との界面に、酸化物、窒化物、炭化物、ホウ化物、フッ化物等からなる原子拡散バリヤ層５を形成しているため、上述したような直交アニールや結晶性向上のためのアニール処理を施した際に、第１の磁性層１と金属バッファ層４との間の原子相互拡散を安定して抑制することができる。また、原子拡散バリヤ層５の平均厚さを 2nm以下とすることにより、金属バッファ層４による膜質改善効果も十分に得ることができる。このように、上記実施形態のＭＲ素子によれば、金属バッファ層４による膜質改善効果が十分に得られると共に、熱拡散による磁気抵抗効果の劣化が抑制できることから、高性能化を達成した上で熱安定性の向上を図ることが可能となる。

【００３２】次に、本発明の第２の磁気抵抗効果素子（ＭＲ素子）を実施するための形態について述べる。

【００３３】図２は、第２のＭＲ素子の一実施形態の要部構成を示す断面図である。図２において、１は第１の磁性層、２は第２の磁性層であり、これら第１および第２の磁性層１、２間には非磁性中間層３が介在されている。これら磁性層１、２間は反強磁性結合しておらず、非結合型の積層膜を構成している。

【００３４】これら磁性層１、２のうち、第１の磁性層１は第１の実施形態で述べたような強磁性体からなる強磁性体層１１と各種軟磁性材料からなる磁性下地層１２との積層膜により構成されている。これらのうち、強磁性体層１１は磁気抵抗効果に寄与する層であり、磁性下地層１２は強磁性体層１１の軟磁気特性を向上させる層である。ここで、前述した強磁性体のうち、特にＣｏやＣｏ系磁性合金のようなＣｏを含む強磁性体は、それら単独では良好な軟磁気特性を実現することが難しいことから、磁性下地層１２を形成することが特に望ましい材料である。

【００３５】磁性下地層１２は、 1種の軟磁性材料からなる軟磁性材料膜で構成してもよいし、また 2種以上の軟磁性材料膜からなる軟磁性材料積層膜で構成してもよい。また、磁性下地層１２の構成材料としては、ＮｉＦｅ合金、ＮｉＦｅＣｏ合金、これら軟磁性合金にＴｉ、Ｖ、Ｃｒ、Ｍｎ、Ｚｎ、Ｎｂ、Ｍｏ、Ｔｃ、Ｈｆ、Ｔａ、Ｗ、Ｒｅ等の添加元素を添加して高抵抗化した合金、Ｃｏに同様な添加元素を添加してアモルファス化した合金、例えばアモルファスＣｏＮｂＺｒ合金等が挙げられる。

【００３６】強磁性体層１１と磁性下地層１２との積層膜からなる第１の磁性層１は、強磁性体層１１が非磁性中間層３と接するように配置されている。なお、必ずしもこの配置に限定されるものではないが、大きなＭＲ変化量を得るためには、上記したような配置とすることが望ましい。また、強磁性体層１１と磁性下地層１２との間は直接磁気的に交換結合させ、膜厚方向で見ると磁化が一体として振舞うことが望ましい。この第１の磁性層１は、信号磁界等の外部磁界により磁化反転する磁性層、いわゆるフリー磁性層である。

【００３７】そして、第１の磁性層１における強磁性体層１１と磁性下地層１２との界面には、原子拡散バリヤ層５が形成されており、これによって熱処理時における強磁性体層１１と磁性下地層１２との間の熱拡散を抑制している。すなわち、原子拡散バリヤ層５を形成することによって、熱拡散による磁気抵抗効果の劣化を抑制することが可能となり、ＭＲ素子の熱安定性が向上する。原子拡散バリヤ層５は熱的に安定で、強磁性体層１１と磁性下地層１２との間の原子相互拡散を抑えることが必要であるが、あまり厚いと強磁性体層１１と磁性下地層１２との間の磁気的結合が切れてしまうため、原子の相互拡散抑制効果に悪影響を及ぼさない範囲で薄くすることが望ましい。このため、原子拡散バリヤ層５の厚さは、平均厚さで 2nm以下とされている。ただしあまり薄すぎると原子拡散バリヤとしての機能が損われるため、平均厚さで 0.5nm以上とすることが好ましい。

【００３８】原子拡散バリヤ層５の構成材料は、第１の実施形態で述べた通りであり、第１の実施形態と同様に、特に形成が容易でかつ原子の拡散抑制機能に優れる自己酸化膜、表面酸化膜、不動態膜等が好ましく用いら

れる。このような原子拡散バリヤ層５の形成方法についても、第１の実施形態で述べた通りである。

【００３９】また、原子拡散バリヤ層５を構成する化合物は、化学量論的に正確な組成でなくてもよく、きれいな結晶格子を組んでいる必要もなく、またアモルファス状態であってもよい。さらに、原子拡散バリヤ層５の形態は、一様に金属バッファ層４の表面を覆っていなければならないものではなく、例えばピンホールが形成された状態、上記した酸化物、窒化物、炭化物、ホウ化物、フッ化物等が島状に存在した状態等、非連続状態で形成されていてもよい。非連続状態に形成することによって、強磁性体層１１の膜質改善効果や第１の磁性層１の磁気的結合を、連続して形成するよりも良好に得ることができる。

【００４０】特に、強磁性体層１１と磁性下地層１２との間の磁気的結合を十分に保つ上で、積極的に前述したような化合物による被覆面積を低下させて、原子拡散バリヤ層５を非連続状態で形成することが好ましい。また、強磁性体層１１と磁性下地層１２との間の磁気的結合を十分に保つ上で、原子拡散バリヤ層５を強磁性体や反強磁性体で形成することも好ましい。原子拡散バリヤ層５を構成する強磁性体としてはスピネルフェライト、Fe_x N等が、また反強磁性体としてはＮｉＯ、Mn_x Ｎ、ＣｏＯ等が例示される。

【００４１】なお、第２の磁性層２は、前述した第１の実施形態と同様に、反強磁性層６あるいは硬磁性層によりバイアス磁界が付与されて磁化固着された、いわゆるピン磁性層である。これら第２の磁性層２および反強磁性層６の構成は、前述した第１の実施形態と同様であり、また非磁性中間層３についても同様である。

【００４２】また、第１の磁性層１および第２の磁性層２には、前述した第１の実施形態と同様に、直交アニールや結晶性向上のためのアニール処理等が施される。これらアニールの処理の条件は、第１の実施形態で述べた通りである。

【００４３】上述した各層によりスピンバルブ積層膜１３が構成されており、このようなスピンバルブ積層膜１３を具備するＭＲ素子においては、第２の磁性層２は磁化固着されているのに対して、第１の磁性層１は外部磁界によって磁化反転するため、非磁性中間層３を挟んで配置された 2つの磁性層１、２の磁化方向の相対的な角度が変化して磁気抵抗効果が得られる。

【００４４】上記実施形態のＭＲ素子においては、強磁性体層１１と磁性下地層１２との界面に、酸化物、窒化物、炭化物、ホウ化物、フッ化物等からなる原子拡散バリヤ層５を形成しているため、上述したような直交アニールや結晶性向上のためのアニール処理を施した際に、強磁性体層１１と磁性下地層１２との間の原子相互拡散を安定して抑制することができる。また、原子拡散バリヤ層５の平均厚さを2nm以下とすることによって、強磁性体層１１と磁性下地層１２との磁気的結合を損うこともないため、磁性下地層１２による強磁性体層１１の軟磁性化効果等を良好に得ることができる。このように、上記実施形態のＭＲ素子によれば、磁性下地層１２による強磁性体層１１の軟磁性化効果等を十分に得られると共に、熱拡散による磁気抵抗効果の劣化が抑制できることから、高性能化を達成した上で熱安定性の向上を図ることが可能となる。

【００４５】本発明の磁気抵抗効果素子には、この素子にセンス電流を供給するための一対のリード電極が接続形成される。このリード電極の構造および磁気抵抗効果素子への接続方法は、用いる磁気抵抗効果に応じて、多数ある公知の技術のいずれかを適用することにより実現できる。

【００４６】例えば、ピン磁性層およびフリー磁性層とこれらに挟持される非磁性中間層との界面におけるスピン依存散乱を主に用いたスピンバルブＧＭＲ素子では、一対のリード電極は本発明の磁気抵抗効果素子の両脇端に電気的に接続形成される。センス電流は非磁性中間層等の膜面に対して垂直方向に流れる。また、例えば強磁性トンネル接合による磁気抵抗効果を用いる場合には、この膜面方向と平行にトンネル電流を流し、このトンネル電流量、電圧変動等を検知する。従って、膜面方向にセンス電流を流すように、一対のリード電極を接続形成する。例えば、一対のリード電極を磁気抵抗効果素子のそれぞれ下面に接続形成する。あるいは、一方のリード電極を磁気抵抗効果素子の上面および下面のいずれかに接続形成し、他方を磁気抵抗効果素子の端部に接続形成することもできる。

【００４７】さらに、リード電極と硬質磁性膜とを積層形成して用いることも可能である。この硬質磁性膜はフリー磁性層の磁区の発生を抑制するために、フリー磁性層に縦バイアスを付与するものである。従って、硬質磁性膜が少なくともフリー磁性層の両脇端に隣接形成されるアバット(abutt) 方式やフリー磁性層の端部を硬質磁性膜に積層形成する方式が適用可能である。

【００４８】本発明の磁気抵抗効果素子は、例えば磁気記録再生装置の再生用ＭＲヘッドのＧＭＲ素子部として使用される。また、本発明の磁気抵抗効果素子をＧＭＲ再生ヘッドに用い、磁気記録ヘッドと一体に形成することも可能である。さらに、本発明の磁気抵抗効果素子は、磁気ヘッドに限らず、ＭＲＡＭ等の磁気記憶装置に使用することも可能である。

【００４９】磁気記録ヘッドは、少なくとも一対の磁極と、媒体対向面において一対の磁極に挟持される磁気ギャップと、一対の磁極に電流磁界を供給する記録コイルを有する。ＧＭＲヘッドと磁気記録ヘッドは順次基板上に積層形成される。記録再生分離型磁気ヘッドでは、磁気記録ヘッドの少なくともいずれかの磁極を再生ヘッドのシールド層として用いることができる。また、記録再

生一体型磁気ヘッドでは、記録ヘッドの磁極を本発明の磁気抵抗効果素子に媒体磁界を誘導する再生ヨークとして用いることができる。この際、磁気抵抗効果素子と再生ヨークとは磁気的に結合させることができる。これらのヘッド構造は公知の技術を用いて実現可能である。

【００５０】図３は、上述した実施形態のＧＭＲ素子を再生ヘッド部に適用した記録再生分離型磁気ヘッドの構造例を示す図である。図３において２１は基板であり、この基板２１としてはAl_2O_3層を有するAl_2O_3・ＴｉＣ基板等が用いられる。このような基板２１の主表面上には、ＮｉＦｅ合金、ＦｅＳｉＡｌ合金、アモルファスＣｏＺｒＮｂ合金等の軟磁性材料からなる下側磁気シールド層２２が形成されている。下側磁気シールド層２２上にはAlO_x等の非磁性絶縁材料からなる下側再生磁気ギャップ２３を介して、例えば前述した実施形態で示したスピンバルブ積層膜等のＧＭＲ膜２４が形成されている。

【００５１】ＧＭＲ膜２４と下側再生磁気ギャップ２３との間には、ＧＭＲ膜２４にバイアス磁界を印加する一対のバイアス磁界印加膜２５が、ＧＭＲ膜２４の磁界検出部すなわち再生トラックの両端部外側に配置されている。また、ＧＭＲ膜２４上には、Ｃｕ、Ａｕ、Ｚｒ、Ｔａ等からなる一対の電極２６が形成されており、この一対の電極２６によりＧＭＲ膜２４にセンス電流が供給される。これらＧＭＲ膜２４、一対のバイアス磁界印加膜２５および一対の電極２６はＧＭＲ素子部２７を構成している。

【００５２】ＧＭＲ素子部２７上には、下側再生磁気ギャップ２３と同様な非磁性絶縁材料からなる上側再生磁気ギャップ２８を介して、下側磁気シールド層２２と同様な軟磁性材料からなる上側磁気シールド層２９が形成されており、これらにより再生ヘッド部としてのシールド型ＧＭＲヘッド３０が構成されている。

【００５３】シールド型ＧＭＲヘッド３０上には、記録ヘッド部として薄膜磁気ヘッド３１が形成されている。薄膜磁気ヘッド３１の下側記録磁極は、上側磁気シールド層２９と同一の磁性層により構成されている。すなわち、シールド型ＭＲヘッド３０の上側磁気シールド層２９は、薄膜磁気ヘッド３１の下側記録磁極を兼ねている。この上側磁気シールド層を兼ねる下側記録磁極２９上には、AlO_x等の非磁性絶縁材料からなる記録磁気ギャップ３２と上側記録磁極３３とが順に形成されて、記録ヘッド部として薄膜磁気ヘッド２１が構成されている。

【００５４】また、図４は上述した実施形態のＧＭＲ素子を適用したＭＲＡＭの一構造例を示す図である。同図に示すＭＲＡＭ４０は、ガラス基板やＳｉ基板等の基板４１上に形成されたＧＭＲ膜４２を有している。このＧＭＲ膜４２は、例えば前述した実施形態で示したスピンバルブ積層膜からなるものである。ＧＭＲ膜４２の上部には、絶縁層４３を介して書き込み電極４４が設けられている。また、ＧＭＲ膜４２の両端部には、Ａｕ等からなるシャント層４５を介して一対の読み出し電極４６が設けられている。このようにして、ＭＲＡＭ４０が構成されている。

【００５５】

【実施例】次に、本発明の具体的な実施例について述べる。

【００５６】実施例１

熱酸化Ｓｉ基板上にスパッタ法によって、まず磁性下地層１２として膜厚10nmのアモルファスＣｏＮｂＺｒ合金膜と膜厚 2nmのＮｉＦｅ合金膜を順に成膜した。ここで、ＮｉＦｅ合金膜は金属バッファ層４を兼ねるものである。

【００５７】上記ＮｉＦｅ合金膜を形成した後に、一旦その表面を大気に晒し、ＮｉＦｅ合金膜上に不動態膜を原子拡散バリヤ層として形成した。なお、この不動態膜の状態を断面ＴＥＭで調べたところ、平均厚さは約 1nmであり、また形成状態は島状不連続であった。

【００５８】次に、表面に不動態膜を形成したＮｉＦｅ合金膜上に、強磁性体層１１として膜厚 3nmの$Co_{90}Fe_{10}$合金膜、非磁性中間層３として膜厚 3nmのＣｕ膜、第２の磁性層２として膜厚 3nmの$Co_{90}Fe_{10}$合金膜、反強磁性層６として膜厚10nmのＩｒＭｎ合金膜、保護層として膜厚 5nmのＴａ膜を順に積層して、スピンバルブ積層膜１３（７）を作製した。

【００５９】一方、本発明との比較例１として、ＮｉＦｅ合金膜を形成した後にその表面を大気に晒すことなく、全層を真空チャンバ内で連続して成膜する以外は、上記実施例１と同様にしてスピンバルブ積層膜を作製した。この比較例１のスピンバルブ積層膜では、ＮｉＦｅ合金膜と$Co_{90}Fe_{10}$合金膜との界面に原子拡散バリヤ層は形成されていない。

【００６０】上記した実施例１および比較例１による各スピンバルブ積層膜をパターニングした後、それぞれ523Kでアニール処理した。このようにして得た各ＭＲ素子のＭＲ変化率を測定した。ＭＲ変化率は 2時間のアニール後、10時間のアニール後、50時間のアニール後、および 100時間のアニール後にそれぞれ測定し、これらの測定結果から実施例によるＭＲ素子と比較例によるＭＲ素子の熱安定性を比較した。各アニール時間経過後のＭＲ変化率の測定結果を表１に示す。

【００６１】

【表１】

	MR変化率(%)				
アニール時間	0時間 (as depo)	2時間	10時間	50時間	100時間
実施例１	6.2%	8.0%	8.0%	8.0%	8.0%
比較例１	6.9%	6.1%	5.9%	5.4%	4.9%

表１から分かるように、一括成膜してＮｉＦｅ合金膜／$Co_{90}Fe_{10}$合金膜界面に原子拡散バリヤ層を形成していない比較例１では、成膜直後のＭＲ変化率は6.9%と比較的良好であるものの、 2時間のアニール後にＭＲ変化率が急激に減少している。そして、その後もアニール時間の経過に伴ってＭＲ変化率が減少し続け、 100時間のアニール後にはＭＲ変化率が4.9%まで減少した。これはＮｉＦｅ合金膜／$Co_{90}Fe_{10}$合金膜界面に原子拡散を抑えるバリヤ層が存在していないために、アニールにより層間の原子相互拡散が進行し、これによってＭＲ変化率が減少したものと考えられる。このように、比較例１のＭＲ素子は熱安定性（耐熱性）の低いものであった。

【００６２】一方、ＮｉＦｅ合金膜の形成後に一旦大気に晒してＮｉＦｅ合金膜／$Co_{90}Fe_{10}$合金膜界面に原子拡散バリヤ層を形成した実施例１では、成膜直後の特性は比較例１より低いものの、 2時間のアニール後にはＭＲ変化率が8.0%まで上昇した。これは 2時間のアニール処理により各層の結晶性等が向上すると共に、ＮｉＦｅ合金膜／$Co_{90}Fe_{10}$合金膜界面の原子拡散が原子拡散バリヤ層により抑えられたためであると考えられる。さらに、長時間のアニールを行っても、ＭＲ変化率は8.0%から減少せず、ＮｉＦｅ合金膜／$Co_{90}Fe_{10}$合金膜界面の原子拡散が抑えられていることが分かる。このように、実施例１のＭＲ素子は熱安定性（耐熱性）に優れるものであった。

【００６３】実施例２

熱酸化Ｓｉ基板上にプラズマスパッタ法によって、まず磁性下地層１２として膜厚10nmのアモルファスＣｏＮｂＺｒ合金膜と膜厚 2nmのＮｉＦｅ合金膜を順に成膜した。ここで、ＮｉＦｅ合金膜は金属バッファ層４を兼ねるものである。

【００６４】上記ＮｉＦｅ合金膜を形成した後に一旦プラズマを消し、真空チャンバ内に酸素を 20%混合したアルゴンガスを導入し、ＮｉＦｅ合金膜の表面に酸化膜を原子拡散バリヤ層として形成した。この際、酸素とアルゴンとの混合ガスの導入圧力や時間を制御することによって、表面酸化膜の厚さを種々変化させた。得られた表面酸化膜の平均厚さは以下の表２に示す通りである。なお、表中の比較例２は表面酸化膜の厚さを本発明の範囲外としたものである。

【００６５】

【表２】

	試料 No	表面酸化膜の平均厚さ (nm)
実施例２	1	0.3
	2	0.5
	3	1.0
比較例２	4	3.0

なお、表２に示した表面酸化膜の厚さは平均厚さであり、その厚さの酸化膜が均質に形成されているとは限らない。このため、表面酸化膜の平均厚さが 0.3nmの実施例２の No1の試料では、表面酸化膜に比較的多数のピンホールが存在していた。

【００６６】次に、表面酸化膜を形成した各ＮｉＦｅ合金膜上に、それぞれ強磁性体層１１として膜厚 3nmの$Co_{90}Fe_{10}$合金膜、非磁性中間層３として膜厚 3nmのＣｕ膜、第２の磁性層２として膜厚 2nmの$Co_{90}Fe_{10}$合金膜、反強磁性層６として膜厚 8nmのＩｒＭｎ合金膜、保護層として膜厚 5nmのＴａ膜を順に積層して、それぞれスピンバルブ積層膜１３（７）を作製した。

【００６７】上記した実施例２および比較例２による各スピンバルブ積層膜をパターニングした後、それぞれ523Kで 2時間アニール処理した。このようにして得た各ＭＲ素子のＭＲ変化率を、成膜直後および 2時間のアニール後にそれぞれ測定した。これらの測定結果を表３に示す。

【００６８】

【表３】

	試料 No	表面酸化膜の平均厚さ(nm)	MR変化率(%)	
			成膜直後	2時間アニール後
実施例2	1	0.3	5.8	6.2
	2	0.5	6.1	7.0
	3	1.0	6.0	8.2
比較例2	4	3.0	5.0	5.2

実施例2による各MR素子は、いずれも 2時間のアニール後にMR変化率が上昇しており、表面酸化膜からなる原子拡散バリヤ層の効果が確認された。ただし、表面酸化膜の厚さが薄い試料ではMR変化率の上昇があまり大きくはなく、若干原子相互拡散が起っていたものと推定されるが、表面酸化膜の厚さを 1nmとした試料では良好なMR変化率が得られている。

【0069】一方、比較例2によるMR素子は、 2時間のアニール後に若干MR変化率が上昇しているものの、当初（成膜直後）のMR変化率が小さいために、結果として十分なMR変化率が得られていない。これは表面酸化膜の厚さを厚くしすぎたために、磁性下地層および金属バッファ層の効果が得られなくなったためと考えられる。また、 fcc配向性が十分に得られず、さらに磁性下地層との磁気的結合が切れているため、軟磁気特性が劣化して保磁力H_cが 3Oe であった。

【0070】

【発明の効果】以上説明したように本発明によれば、金属バッファ層と磁性層、あるいは磁性下地層と強磁性体層との間の熱拡散を抑制できることから、高性能で熱安定性に優れた磁気抵抗効果素子を提供することが可能となる。

【図面の簡単な説明】

【図1】　本発明の第1の磁気抵抗効果素子の一実施形態の要部構造を示す断面図である。

【図2】　本発明の第2の磁気抵抗効果素子の一実施形態の要部構造を示す断面図である。

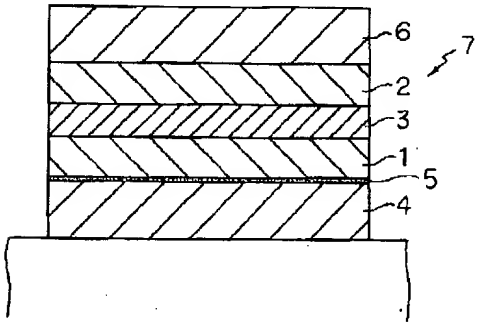
【図3】　本発明の磁気抵抗効果素子を使用した記録再生分離型磁気ヘッドの一構成例を示す断面図である。

【図4】　本発明の磁気抵抗効果素子を使用したMRAMの一構成例を示す断面図である。

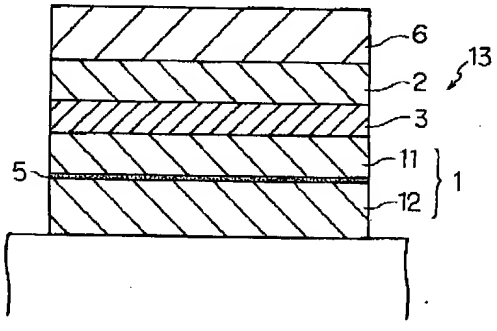
【符号の説明】

1……第1の磁性層
2……第2の磁性層
3……非磁性中間層
4……金属バッファ層
5……原子拡散バリヤ層
7、13……スピンバルブ膜
11…強磁性体層
12…磁性下地層

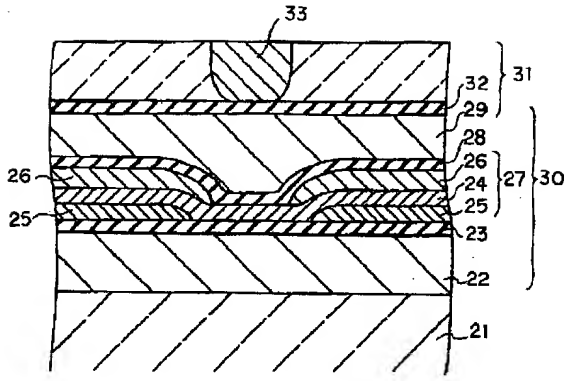
【図1】



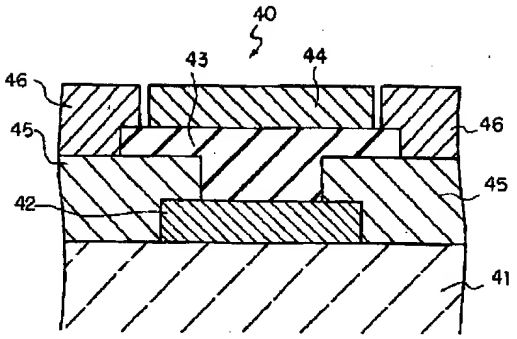
【図2】



【図3】



【図4】



フロントページの続き

(72)発明者　福澤　英明
神奈川県川崎市幸区堀川町72　株式会社東芝川崎事業所内

(72)発明者　岩崎　仁志
神奈川県川崎市幸区堀川町72　株式会社東芝川崎事業所内

(72)発明者　佐橋　政司
神奈川県川崎市幸区堀川町72　株式会社東芝川崎事業所内

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(71)Applicant : TOSHIBA CORP
(72)Inventor : KAMIGUCHI YUZO
SAITO AKIKO
SAITO KAZUHIRO
FUKUZAWA HIDEAKI
IWASAKI HITOSHI
SAHASHI MASASHI

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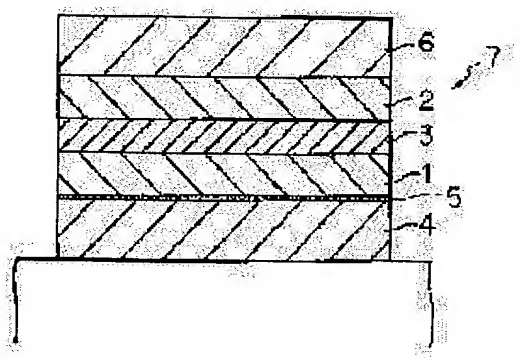
(54) MAGNETORESISTIVE EFFECT DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To restrain a magnetoresistive effect device with a spin valve film from dissipating heat, so as to improve it in thermal stability without deteriorat ing its performance.
SOLUTION: A magnetoresistive effect device is equipped with a spin valve film 7, composed of a first magnetic layer 1 formed on a metal buffer layer 4, a non-magnetic intermediate layer 3 and a second magnetic layer 2. An atom diffusion barrier layer 5 formed of oxide, nitride, carbide, boride, fluoride or the like of thickness 2nm or below is provided at an interface between the metal buffer layer 4 and the first magnetic layer 1. Or a magnetoresistive effect device is equipped with a spin valve film 7, composed of a first magnetic layer of laminated film structure which consists of a magnetic base layer and a ferromagnetic layer, a second magnetic layer, and a non-magnetic intermediate layer interposed between them, wherein an atom diffusion barrier layer formed of oxide, nitride, carbide, boride, fluoride or the like of thickness 2nm or below is provided at an interface between the magnetic base layer and the ferromagnetic layer 1.



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* NOTICES *

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2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]
[Claim 1] In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 1st magnetic layer formed on a metal buffer layer, the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer, average thickness to an interface of said metal buffer layer and 1st magnetic layer A magneto-resistive effect element characterized by establishing an atomic diffusion barrier layer 2nm or less.
[Claim 2] The 1st magnetic layer which consists of a ferromagnetic containing Co formed on a metal buffer layer which has a fcc crystal structure The 2nd magnetic layer A spin bulb film which has the nonmagnetic middle class stationed between said 1st magnetic layer and 2nd magnetic layer It is as being the magneto-resistive effect element equipped with the above, and being chosen as an interface of said metal buffer layer and 1st magnetic layer out of an oxide, a nitride, carbide, a boride, and a fluoride that it is few. It is characterized by establishing an atomic diffusion barrier layer which uses one sort as a principal component.
[Claim 3] In a magneto-resistive effect element according to claim 2, average thickness said atomic diffusion barrier layer A magneto-resistive effect element characterized by being 2nm or less.
[Claim 4] The 1st magnetic layer which consists of a cascade screen of a magnetic substrate layer and a ferromagnetic layer The 2nd magnetic layer A spin bulb film which has the nonmagnetic middle class stationed between said 1st magnetic layer and 2nd magnetic layer It is the magneto-resistive effect element equipped with the above, and average thickness to an interface of said magnetic substrate layer and ferromagnetic layer It is characterized by establishing an atomic diffusion barrier layer 2nm or less.
[Claim 5] The 1st magnetic layer which consists of a cascade screen of a magnetic substrate layer and a ferromagnetic layer containing Co The 2nd magnetic layer A spin bulb film which has the nonmagnetic middle class stationed between said 1st magnetic layer and 2nd magnetic layer It is as being the magneto-resistive effect element equipped with the above, and being chosen as an interface of said magnetic substrate layer and ferromagnetic layer out of an oxide, a nitride, carbide, a boride, and a fluoride that it is few. It is characterized by establishing an atomic diffusion barrier layer which uses one sort as a principal component.
[Claim 6] In a magneto-resistive effect element according to claim 5, average thickness said atomic diffusion barrier layer A magneto-resistive effect element characterized by being 2nm or less.
[Claim 7] A magneto-resistive effect element characterized by forming a pinhole in said atomic diffusion barrier layer in claim 1, claim 2, and a magneto-resistive effect element according to claim 4 or 5.
[Claim 8] It is the magneto-resistive effect element characterized by said atomic diffusion barrier layer consisting of a ferromagnetic or the antiferromagnetic substance in claim 1, claim 2, and a magneto-resistive effect element according to claim 4 or 5.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the magneto-resistive effect element which used the spin bulb film.
[0002]
[Description of the Prior Art] Generally, read-out of the information recorded on magnetic-recording data medium moved relatively the magnetic head for playback which has a coil to the record medium, and has been performed by the method of detecting the voltage by which induction is carried out to a coil by the electromagnetic induction then generated. On the other hand, when reading information, using a magneto-resistive effect element (henceforth, MR element) is also known (reference, such as IEEE MAG-7,150 (1971)). The magnetic head (it is hereafter described as an MR head) using MR element uses the phenomenon in which the electric resistance of a certain kind of ferromagnetic changes according to the strength of an external magnetic field.
[0003] Since small and large capacity-ization of magnetic-recording data medium are advanced and the relative velocity of the magnetic head for playback at the time of information read-out and magnetic-recording data medium is becoming small in recent years, even if it is a small relative velocity, the expectation for the MR head which can take out a big output is growing. Here, the nickel-Fe alloy ******** permalloy system alloy has been used for the portion (it is hereafter called MR element) from which the external magnetic field of an MR head is sensed, and resistance changes. However, a permalloy system alloy has inadequate magnetic-reluctance rate of change as a MR element for magnetic-recording data medium by which magnetic-reluctance rate of change is about 3% at the maximum, and what has good soft magnetic characteristics was large-capacity[small and]-ized. For this reason, what shows a high sensitivity magneto-resistive effect as a MR element material is desired.
[0004] It is checked that a magneto-resistive effect with huge multilayer which the laminating of a ferromagnetic metal membrane and the non-magnetic metal film was carried out [multilayer] by turns on some conditions, and carried out antiferromagnetism association of between the approaching ferromagnetic metal membranes like Fe/Cr or Co/Cu and so-called artificial grid film is shown to such want. According to the artificial grid film, it is reported that the big magnetic-reluctance rate of change exceeding 100% at the maximum is shown (Phys.Rev.Lett., Vol. 61, 2474 (1988), Phys.Rev.Lett., Vol. reference, such as 64 and 2304 (1990)). However, since an artificial grid film has the high saturation magnetic field, it is unsuitable for MR element.
[0005] On the other hand, by the multilayer of the sandwich structure of a ferromagnetic layer / non-magnetic layer / ferromagnetic layer, even when a ferromagnetic layer does not carry out antiferromagnetism association, the example which realized the big magneto-resistive effect is reported. That is, the non-magnetic layer was pinched. Exchange bias is exerted on one side of two ferromagnetic layers, magnetization is fixed to it, and flux reversal of the ferromagnetic layer of another side is carried out by external magnetic fields (signal magnetic field etc.). Thereby, it has been arranged on both sides of a non-magnetic layer. A big magneto-resistive effect is acquired by changing the relative angle of the magnetization direction of two ferromagnetic layers. The such type multilayer is called the spin bulb film (reference, such as Phys.Rev.B., Vol.45,806 (1992), J.Appl.Phys., Vol.69, and 4774 (1991)). Although the magnetic-reluctance rate of change of a spin bulb film is small compared with an artificial grid film, since magnetization can be saturated with a low magnetic field, it is suitable for MR element. It has a practically great hope for the MR head using such a spin bulb film.
[0006]
[Problem(s) to be Solved by the Invention] By the way, in MR element using the spin bulb film mentioned above, it is made important to raise the crystal stacking tendency of a ferromagnetic layer etc. and to raise soft magnetic

characteristics. For example, by the spin bulb film which used a Co system ferromagnetic like Co or Co system alloy for the ferromagnetic layer, if a direct Co system ferromagnetic layer is formed on an amorphous system material, a crystal stacking tendency will fall, and soft magnetic characteristics will deteriorate. Then, raising a crystal stacking tendency is examined by forming the metal membrane which has a fcc crystal structure as a buffer layer, and forming Co system ferromagnetic layer on this metal buffer layer.

[0007] However, when soft magnetic materials, such as a NiFe alloy, are used as the above-mentioned metal buffer layer, thermal diffusion will happen easily between Co system ferromagnetics, and a magneto-resistive effect will deteriorate. Moreover, although forming the ferromagnetic layer which carries out flux reversal by the external magnetic field on the magnetic substrate layer which consists of various soft magnetic materials is also examined in order to raise the soft magnetic characteristics of a spin bulb film and to raise element sensitivity, also in such a case, thermal diffusion will happen between a ferromagnetic layer and a magnetic substrate layer, and a magneto-resistive effect will deteriorate.

[0008] In the manufacture process of MR element using a spin bulb film, deterioration of the magneto-resistive effect by the thermal diffusion mentioned above from heat treatment being indispensable is a serious problem. Thus, thermal stability (thermal resistance) has the problem of being low, and MR element using the conventional spin bulb film has been the technical problem that improvement in the thermal stability by control of thermal diffusion is big.

[0009] This invention was made in order to cope with such a technical problem, and it aims at offering the magneto-resistive effect element of the high performance excellent in thermal stability by controlling thermal diffusion.

[0010]

[Means for Solving the Problem] As indicated to claim 1, the 1st magneto-resistive effect element in this invention In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 1st magnetic layer formed on a metal buffer layer, the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer Average thickness to an interface of said metal buffer layer and 1st magnetic layer It is characterized by establishing an atomic diffusion barrier layer 2nm or less.

[0011] The 1st magnetic layer which indicated the 1st magneto-resistive effect element to claim 2 further and which consists of like and a ferromagnetic containing Co formed on a metal buffer layer which has a fcc crystal structure, In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer It is as being chosen as an interface of said metal buffer layer and 1st magnetic layer out of an oxide, a nitride, carbide, a boride, and a fluoride that it is few. It is characterized by establishing an atomic diffusion barrier layer which uses one sort as a principal component.

[0012] Moreover, the 2nd magneto-resistive effect element in this invention The 1st magnetic layer which consists of a cascade screen of a magnetic substrate layer and a ferromagnetic layer as indicated to claim 4, In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer Average thickness to an interface of said magnetic substrate layer and ferromagnetic layer It is characterized by establishing an atomic diffusion barrier layer 2nm or less.

[0013] The 1st magnetic layer which consists of a cascade screen of a magnetic substrate layer and a ferromagnetic layer containing Co as the 2nd magneto-resistive effect element was further indicated to claim 5, In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer It is as being chosen as an interface of said magnetic substrate layer and ferromagnetic layer out of an oxide, a nitride, carbide, a boride, and a fluoride that it is few. It is characterized by establishing an atomic diffusion barrier layer which uses one sort as a principal component.

[0014] In the 1st magneto-resistive effect element, since an atomic diffusion barrier layer which was mentioned above to an interface of a metal buffer layer and the 1st magnetic layer is established, while being able to control atomic counter diffusion between a metal buffer layer and the 1st magnetic layer at the time of heat treatment good, a membraneous improvement effect of the 1st magnetic layer by metal buffer layer is acquired. Therefore, after heat treatment, it is stabilized, a good magneto-resistive effect can be acquired, and it becomes possible to obtain good soft magnetic characteristics simultaneously.

[0015] Moreover, in the 2nd magneto-resistive effect element, since an atomic diffusion barrier layer which was mentioned above to an interface of a magnetic substrate layer and a ferromagnetic layer is established, atomic counter diffusion between magnetic substrate layers and ferromagnetic layers at the time of heat treatment can be controlled good similarly. Therefore, it becomes possible to be stabilized and to acquire a good magneto-resistive effect after heat treatment.

[0016]

[Embodiment of the Invention] Hereafter, the gestalt for carrying out this invention is explained.

[0017] First, the gestalt for carrying out the 1st magneto-resistive effect element (MR element) of this invention is described.

[0018] Drawing 1 is the cross section showing the important section configuration of 1 operation gestalt of 1st MR element. In this drawing, 1 is the 1st magnetic layer, 2 is the 2nd magnetic layer, and the nonmagnetic interlayer 3 intervenes between these 1st and 2nd magnetic layers 1 and 2. Antiferromagnetism association is not carried out between these magnetic layers 1 and 2, but it constitutes the cascade screen of an uncombined mold.

[0019] The 1st and 2nd magnetic layers 1 and 2 are constituted by the ferromagnetic containing Co like for example, Co simple substance or Co system magnetism alloy, or ferromagnetic like a NiFe alloy. Especially as a ferromagnetic containing Co, it is [among these] desirable to use Co system magnetism alloy with which the bulk effect and the interface effect which affect MR variation can both be enlarged, and big MR variation is obtained by this.

[0020] as Co system magnetism alloy which was described above -- Co -- Fe, nickel, Au, Ag, Cu, Pd, Pt, Ir, Rh, Ru, Os, Hf, etc. one sort -- or -- The alloy which added two or more sorts is mentioned. The amount of alloying elements It is desirable to consider as five to 50 atom % , and it is in a pan. It is desirable to consider as the range of 8 - 20 atom % . This is because there is a possibility that the interface effect may decrease greatly shortly when a bulk effect will not fully increase if there are too few amounts of alloying elements, but reverse has too many amounts of alloying elements. When obtaining big MR variation, as for an alloying element, it is desirable to use especially Fe.

[0021] Moreover, as for the thickness of the 1st and 2nd magnetic layers 1 and 2, it is [that big MR variation is obtained and generating of a Barkhausen noise can be controlled] desirable to consider as the range of 1-30nm.

[0022] Among the magnetic layers 1 and 2 mentioned above, the 1st magnetic layer 1 is formed on the metal buffer layer 4, and the membraneous improvement by improvement in the crystal stacking tendency of the 1st magnetic layer 1 is achieved by this. When using the ferromagnetic containing Co which was described above to the 1st magnetic layer 1, it is a metal buffer layer 4. The metallic material which has the fcc crystal structure, for example, a NiFe alloy, a NiFeCo alloy, these The alloy which added and formed alloying elements, such as Ti, V, Cr, Mn, Zn, Nb, Mo, Tc, Hf, Ta, W, and Re, into high resistance into the alloy of the fcc crystal structure is illustrated. A NiFe alloy, a NiFeCo alloy, etc. function also as a magnetic substrate layer mentioned later among these. Moreover, when using ferromagnetics, such as a NiFe alloy, for the 1st magnetic layer 1, Ta, Ti, Cr, Cu, Au, Ag, these alloys, etc. can be used as a metal buffer layer 4. The 1st magnetic layer 1 is the magnetic layer which carries out flux reversal by external magnetic fields, such as a signal magnetic field, and the so-called free magnetic layer.

[0023] And the atomic diffusion barrier layer 5 is formed in the interface of the 1st magnetic layer 1 and the metal buffer layer 4, and the thermal diffusion of the atom between the 1st magnetic layer 1 and the metal buffer layers 4 at the time of heat treatment is controlled by this to it. That is, by forming the atomic diffusion barrier layer 5, it becomes possible to control deterioration of the magneto-resistive effect by thermal diffusion, and the thermal stability of MR element improves. The atomic diffusion barrier layer 5 is thermally stable, and although it is required to suppress the atomic counter diffusion between the 1st magnetic layer 1 and the metal buffer layer 4, since the membraneous improvement effect by the metal buffer layer 4 will no longer be acquired if not much thick, it is desirable to make it thin in the range which does not have an adverse effect on atomic counter diffusion depressor effect. For this reason, the thickness of the atomic diffusion barrier layer 5 is by average thickness. It may be 2nm or less. However, since the function as an atomic diffusion barrier will be spoiled if too not much thin, it is by average thickness. It is desirable to be referred to as 0.5nm or more.

[0024] As a component of the atomic diffusion barrier layer 5, a stable oxide, a nitride, carbide, a boride, a fluoride, etc. can be used thermally, and these may be used with gestalten, such as not only when using as a simple substance, but mixture, and a conjugated compound. Among these, especially formation is easy and the autooxidation film which is excellent in an atomic diffusion control function, a scaling film, a passive state film, etc. are used preferably. The atomic diffusion barrier layer 5 which consists of these compounds can be formed by once exposing the front face to atmospheric air, or exposing into the ambient atmosphere containing oxygen, nitrogen, carbon, boron, a fluorine, etc., after forming the metal buffer layer 4. Moreover, ion-implantation can be used or it can form by exposing to the plasma etc.

[0025] Moreover, you may not be a presentation exact to stoichiometric, and the compound which constitutes the atomic diffusion barrier layer 5 does not need to construct the beautiful crystal lattice, and may be in an amorphous condition. Furthermore, the gestalt of the atomic diffusion barrier layer 5 must not cover the front face of the metal buffer layer 4 uniformly, and after [, such as a condition, / discontinuous] the condition that the pinhole was formed for example, the above-mentioned oxide, a nitride, carbide, the boride, the fluoride, etc. have existed in the shape of an island, it may be formed. It is more more desirable for a pinhole etc. to be in the degree which does not have an adverse effect on atomic counter diffusion depressor effect. This is because there is a possibility that a membraneous improvement effect and

magnetic association may be reduced. When the above point is taken into consideration, the average size of a pinhole is comparable as the distance between the pinholes which adjoin mutually, or it is desirable that it is smaller than it.

[0026] On the other hand, magnetization fixing of the bias magnetic field is given and carried out by the hard magnetism layer which consists of an antiferromagnetism layer 6 which consists of the IrMn film formed on it, a FeMn film, a NiO film, etc., or a CoPt film, and the 2nd magnetic layer 2 is the so-called pin magnetic layer. In addition, for example, what [not only] carried out magnetization fixing of the magnetization of a ferromagnetic layer in the antiferromagnetism layer 6 grade as described above but a hard magnetism layer etc. can also be directly used for the 2nd magnetic layer 2 as this pin magnetic layer.

[0027] Here, when raising the linearity responsibility of MR element, as for the magnetization direction of the 1st magnetic layer 1 and the 2nd magnetic layer 2, it is desirable that an external magnetic field makes it intersect perpendicularly in the state of zero for example. Such a magnetization condition can be acquired by performing annealing treatment as shown below. namely, (1)1kOe while impressing the magnetic field of a degree -- about 523K temperature After holding for about 1 hour (2) -- as it is -- 1kOe It cools to about 483K temperature all over the magnetic field of a degree. The 90 degrees of the impression directions of a magnetic field are rotated, and it cools to a room temperature in the place used as about (3)483K temperature., By such annealing treatment (it is hereafter called rectangular annealing), it is stabilized and the magnetization condition made to intersect perpendicularly can be acquired. The concrete magnetization direction is desirable in making the magnetization direction of the 1st magnetic layer 1 into the truck cross direction, and making the magnetization direction of the 2nd magnetic layer 2 into a vertical direction to the data-medium opposed face which intersects perpendicularly with the magnetization direction of the 1st magnetic layer 1.

[0028] Moreover, annealing treatment to the 1st and 2nd magnetic layers 1 and 2 is carried out not only the above-mentioned rectangular annealing but in order to raise the crystallinity of the 1st and 2nd magnetic layers 1 and 2. At in this case, about 100-400K temperature Annealing treatment is performed on the conditions of 1 minute - about 10 hours.

[0029] The magnetic layer 1 mentioned above and the nonmagnetic interlayer 3 stationed among two are constituted by a paramagnetism material, a diamagnetism material, an antiferromagnetism material, the spin glass, etc. The alloy which specifically makes a principal component the paramagnetic alloy, Pd and Pt, and these containing Cu, Au, Ag, or these and a magnetic element is illustrated. Here, it is the nonmagnetic interlayer's 3 thickness. It is desirable to set it as the range of about 2-5nm. if the nonmagnetic interlayer's 3 thickness exceeds 2nm -- resistance change sensitivity -- enough -- it cannot obtain -- moreover -- It becomes difficult to carry out small enough switched connection between a magnetic layer 1 and 2 to it being less than 5nm.

[0030] The spin bulb cascade screen 7 was constituted by each class mentioned above, and in MR element possessing such a spin bulb cascade screen 7, the 2nd magnetic layer 2 has been arranged on both sides of the nonmagnetic interlayer 3 in order to carry out flux reversal of the 1st magnetic layer 1 by the external magnetic field to magnetization fixing being carried out. The relative angle of the magnetization direction of two magnetic layers 1 and 2 changes, and a magneto-resistive effect is acquired.

[0031] In MR element of the above-mentioned operation gestalt, since the atomic diffusion barrier layer 5 which becomes the interface of the 1st magnetic layer 1 and the metal buffer layer 4 from an oxide, a nitride, carbide, a boride, a fluoride, etc. is formed, when annealing treatment of the sake on rectangular annealing which was mentioned above, or a crystal disposition is performed, it is stabilized and the atomic counter diffusion between the 1st magnetic layer 1 and the metal buffer layer 4 can be controlled. Moreover, average thickness of the atomic diffusion barrier layer 5 By being referred to as 2nm or less, the membraneous improvement effect by the metal buffer layer 4 can also fully be acquired. Thus, according to the MR element of the above-mentioned operation gestalt, since deterioration of the magneto-resistive effect by thermal diffusion can be controlled while the membraneous improvement effect by the metal buffer layer 4 is fully acquired, it becomes possible to aim at improvement in thermal stability, after attaining high performance-ization.

[0032] Next, the gestalt for carrying out the 2nd magneto-resistive effect element (MR element) of this invention is described.

[0033] Drawing 2 is the cross section showing the important section configuration of 1 operation gestalt of 2nd MR element. In drawing 2, 1 is the 1st magnetic layer, 2 is the 2nd magnetic layer, and the nonmagnetic interlayer 3 intervenes between these 1st and 2nd magnetic layers 1 and 2. Antiferromagnetism association is not carried out between these magnetic layers 1 and 2, but it constitutes the cascade screen of an uncombined mold.

[0034] The 1st magnetic layer 1 is constituted among these magnetic layers 1 and 2 by the cascade screen with the magnetic substrate layer 12 which consists of a ferromagnetic layer 11 which consists of a ferromagnetic which was

stated with the 1st operation gestalt, and various soft magnetic materials. Among these, the ferromagnetic layer 11 is a layer which contributes to a magneto-resistive effect, and the magnetic substrate layer 12 is a layer which raises the soft magnetic characteristics of the ferromagnetic layer 11. Here, among the ferromagnetics mentioned above, if independent, since these things [realizing good soft magnetic characteristics] are difficult for especially the ferromagnetic containing Co or Co like Co system magnetism alloy, it is a material with especially desirable forming the magnetic substrate layer 12.

[0035] the soft-magnetic-materials film which consists of a magnetic substrate layer 12 and one sort of soft magnetic materials -- you may constitute -- moreover -- You may constitute from a soft-magnetic-materials cascade screen which consists of two or more sorts of soft-magnetic-materials films. Moreover, as a component of the magnetic substrate layer 12, a NiFe alloy, a NiFeCo alloy, the alloy that added and formed alloying elements, such as Ti, V, Cr, Mn, Zn, Nb, Mo, Tc, Hf, Ta, W, and Re, into high resistance into these soft magnetism alloy, and the alloy which added and made amorphous the same alloying element as Co, for example, an amorphous CoNbZr alloy etc., are mentioned.

[0036] The 1st magnetic layer 1 which consists of a cascade screen of the ferromagnetic layer 11 and the magnetic substrate layer 12 is arranged so that the ferromagnetic layer 11 may touch the nonmagnetic interlayer 3. In addition, although not necessarily limited to this arrangement, in order to obtain big MR variation, considering as arrangement which was described above is desirable. Moreover, when switched connection is carried out directly between the ferromagnetic layer 11 and the magnetic substrate layer 12 magnetically and it sees in the direction of thickness, it is desirable for magnetization to act as one. This 1st magnetic layer 1 is the magnetic layer which carries out flux reversal by external magnetic fields, such as a signal magnetic field, and the so-called free magnetic layer.

[0037] And the atomic diffusion barrier layer 5 is formed in the interface of the ferromagnetic layer 11 and the magnetic substrate layer 12 in the 1st magnetic layer 1, and the thermal diffusion between the ferromagnetic layers 11 and the magnetic substrate layers 12 at the time of heat treatment is controlled by this to it. That is, by forming the atomic diffusion barrier layer 5, it becomes possible to control deterioration of the magneto-resistive effect by thermal diffusion, and the thermal stability of MR element improves. The atomic diffusion barrier layer 5 is thermally stable, and although it is required to suppress the atomic counter diffusion between the ferromagnetic layer 11 and the magnetic substrate layer 12, if not much thick, in order that magnetic association between the ferromagnetic layer 11 and the magnetic substrate layer 12 may go out, it is desirable to make it thin in the range which does not have an adverse effect on atomic counter diffusion depressor effect. For this reason, the thickness of the atomic diffusion barrier layer 5 is by average thickness. It may be 2nm or less. However, since the function as an atomic diffusion barrier will be spoiled if too not much thin, it is by average thickness. It is desirable to be referred to as 0.5nm or more.

[0038] The component of the atomic diffusion barrier layer 5 is as the 1st operation gestalt having described, like the 1st operation gestalt, especially formation is easy and the autooxidation film which is excellent in an atomic diffusion control function, a scaling film, a passive state film, etc. are used preferably. It is as the 1st operation gestalt having also described the formation method of such an atomic diffusion barrier layer 5.

[0039] Moreover, you may not be a presentation exact to stoichiometric, and the compound which constitutes the atomic diffusion barrier layer 5 does not need to construct the beautiful crystal lattice, and may be in an amorphous condition. Furthermore, the gestalt of the atomic diffusion barrier layer 5 must not cover the front face of the metal buffer layer 4 uniformly, and after [, such as a condition, / discontinuous] the condition that the pinhole was formed for example, the above-mentioned oxide, a nitride, carbide, the boride, the fluoride, etc. have existed in the shape of an island, it may be formed. By forming in a discontinuous condition, it can obtain good rather than it forms magnetic association of the membraneous improvement effect of the ferromagnetic layer 11, or the 1st magnetic layer 1 continuously.

[0040] It is desirable to reduce coat area with a compound which was positively mentioned above, and to form the atomic diffusion barrier layer 5 in the discontinuous condition, when fully maintaining magnetic association between the ferromagnetic layer 11 and the magnetic substrate layer 12 especially. Moreover, when fully maintaining magnetic association between the ferromagnetic layer 11 and the magnetic substrate layer 12, it is also desirable to form the atomic diffusion barrier layer 5 with a ferromagnetic or the antiferromagnetic substance. A spinel ferrite, Fex N, etc. are illustrated as a ferromagnetic which constitutes the atomic diffusion barrier layer 5, and NiO, Mnx N, CoO, etc. are illustrated as the antiferromagnetic substance.

[0041] In addition, the 2nd magnetic layer 2 is the so-called pin magnetic layer by which the bias magnetic field was given by the antiferromagnetism layer 6 or the hard magnetism layer, and magnetization fixing was carried out like the 1st operation gestalt mentioned above. The configuration of these 2nd magnetic layers 2 and the antiferromagnetism layer 6 is the same as that of the 1st operation gestalt mentioned above, and is the same also about the nonmagnetic interlayer 3.

[0042] Moreover, rectangular annealing, annealing treatment of the sake on a crystal disposition, etc. are performed to

the 1st magnetic layer 1 and 2nd magnetic layer 2 like the 1st operation gestalt mentioned above. The conditions of processing of these annealing are as the 1st operation gestalt having described.

[0043] The spin bulb cascade screen 13 was constituted by each class mentioned above, and in MR element possessing such a spin bulb cascade screen 13, the 2nd magnetic layer 2 has been arranged on both sides of the nonmagnetic interlayer 3 in order to carry out flux reversal of the 1st magnetic layer 1 by the external magnetic field to magnetization fixing being carried out. The relative angle of the magnetization direction of two magnetic layers 1 and 2 changes, and a magneto-resistive effect is acquired.

[0044] In MR element of the above-mentioned operation gestalt, since the atomic diffusion barrier layer 5 which becomes the interface of the ferromagnetic layer 11 and the magnetic substrate layer 12 from an oxide, a nitride, carbide, a boride, a fluoride, etc. is formed, when annealing treatment of the sake on rectangular annealing which was mentioned above, or a crystal disposition is performed, it is stabilized and the atomic counter diffusion between the ferromagnetic layer 11 and the magnetic substrate layer 12 can be controlled. Moreover, since magnetic association with the ferromagnetic layer 11 and the magnetic substrate layer 12 is not spoiled by setting average thickness of the atomic diffusion barrier layer 5 to 2nm or less, the soft magnetism-ized effect of the ferromagnetic layer 11 by the magnetic substrate layer 12 etc. can be acquired good. Thus, according to the MR element of the above-mentioned operation gestalt, since deterioration of the magneto-resistive effect by thermal diffusion can be controlled while fully being able to acquire the soft magnetism-ized effect of the ferromagnetic layer 11 by the magnetic substrate layer 12 etc., it becomes possible to aim at improvement in thermal stability, after attaining high performance-ization.

[0045] Connection formation of the lead electrode of the couple for supplying sense current to this element is carried out at the magneto-resistive effect element of this invention. The connection method to the structure and the magneto-resistive effect element of this lead electrode is realizable by applying either of the well-known a large number technology according to the magneto-resistive effect to be used.

[0046] For example, with the spin bulb GMR element using spin dependence dispersion in the interface of a pin magnetic layer and a free magnetic layer, and the nonmagnetic middle class pinched by these, connection formation of the lead electrode of a couple is mainly electrically carried out to both **** of the magneto-resistive effect element of this invention. Sense current flows perpendicularly to film surfaces, such as a nonmagnetic interlayer. Moreover, in using the magneto-resistive effect by the ferromagnetic tunnel junction, for example, it detects tunnel current for a sink, this amount of tunnel current, voltage fluctuation, etc. to these direction of a film surface and parallel. Therefore, connection formation of the lead electrode of a couple is carried out so that sense current may be passed in the direction of a film surface. for example, the lead electrode of a couple -- each of a magneto-resistive effect element -- connection formation is carried out on the underside. Or connection formation of one lead electrode can be carried out at either the upper surface of a magneto-resistive effect element, and an underside, and connection formation of another side can also be carried out at the edge of a magneto-resistive effect element.

[0047] Furthermore, it is also possible to carry out laminating formation and to use a lead electrode and a hard magnetic film. This hard magnetic film gives vertical bias to a free magnetic layer, in order to control generating of the magnetic domain of a free magnetic layer. Therefore, ABATTO by which contiguity formation of the hard magnetic film is carried out at least at both **** of a free magnetic layer (abutt) The method which carries out laminating formation can apply the edge of a method or a free magnetic layer to a hard magnetic film.

[0048] The magneto-resistive effect element of this invention is used as the GMR element section of the MR head for playback of a magnetic recorder and reproducing device. Moreover, it is also possible to use the magneto-resistive effect element of this invention for the GMR reproducing head, and to form in a magnetic-recording head and one. Furthermore, not only the magnetic head but the magneto-resistive effect element of this invention can be used for magnetic storage, such as MRAM.

[0049] A magnetic-recording head has the record coil which supplies a current magnetic field to the magnetic pole of a couple, the magnetic gap pinched by the magnetic pole of a couple in a data-medium opposed face, and the magnetic pole of a couple at least. Laminating formation of a GMR head and the magnetic-recording head is carried out on a substrate one by one. In the record playback discrete-type magnetic head, even if there are few magnetic-recording heads, one of magnetic poles can be used as a shield layer of the reproducing head. Moreover, in the record playback one apparatus magnetic head, the magnetic pole of a recording head can be used for the magneto-resistive effect element of this invention as a playback yoke which guides a data-medium magnetic field. Under the present circumstances, a magneto-resistive effect element and a playback yoke can be combined magnetically. Such head structures are realizable using well-known technology.

[0050] Drawing 3 is drawing showing the example of structure of the record playback discrete-type magnetic head which applied the GMR element of the operation gestalt mentioned above to the reproducing-head section. In drawing

3 , 21 is a substrate and it is aluminum 2O3 as this substrate 21. aluminum2 O3, the TiC substrate, etc. which has a layer are used. On the main front face of such a substrate 21, the bottom magnetic-shielding layer 22 which consists of soft magnetic materials, such as a NiFe alloy, a FeSiAl alloy, and an amorphous CoZrNb alloy, is formed. the bottom magnetic-shielding layer 22 top -- AlOx etc. -- the GMR films 24, such as a spin bulb cascade screen shown with the operation gestalt mentioned above, are formed through the bottom playback magnetic gap 23 which consists of a nonmagnetic insulating material.

[0051] Between the GMR film 24 and the bottom playback magnetic gap 23, the bias magnetic field impression film 25 of the couple which impresses a bias magnetic field to the GMR film 24 is arranged at the magnetic field detecting-element, i.e., ends outside of regenerative track, side of the GMR film 24. Moreover, on the GMR film 24, the electrode 26 of a couple which consists of Cu, Au, Zr, Ta, etc. is formed, and sense current is supplied to the GMR film 24 with the electrode 26 of this couple. These GMR film 24, the bias magnetic field impression film 25 of a couple, and the electrode 26 of a couple constitute the GMR element section 27.

[0052] On the GMR element section 27, the upside magnetic-shielding layer 29 which consists of the same soft magnetic materials as the bottom magnetic-shielding layer 22 is formed through the upside playback magnetic gap 28 which consists of the same nonmagnetic insulating material as the bottom playback magnetic gap 23, and shield mold GMR head 30 as the reproducing-head section is constituted by these.

[0053] On shield mold GMR head 30, the thin film magnetic head 31 is formed as the recording head section. The bottom record magnetic pole of the thin film magnetic head 31 is constituted by the same magnetic layer as the upside magnetic-shielding layer 29. That is, the upside magnetic-shielding layer 29 of shield mold MR head 30 serves as the bottom record magnetic pole of the thin film magnetic head 31. the bottom record magnetic pole 29 top which serves as a besides side magnetic-shielding layer -- AlOx etc. -- the record magnetic gap 32 and the upside record magnetic pole 33 which consist of a nonmagnetic insulating material are formed in order, and the thin film magnetic head 21 is constituted as the recording head section.

[0054] Moreover, drawing 4 is drawing showing the example of 1 structure of MRAM which applied the GMR element of the operation gestalt mentioned above. MRAM40 shown in this drawing has the GMR film 42 formed on the substrates 41, such as a glass substrate and Si substrate. This GMR film 42 consists of a spin bulb cascade screen shown with the operation gestalt mentioned above, for example. It writes in the upper part of the GMR film 42 through an insulating layer 43, and the electrode 44 is formed in it. Moreover, the read-out electrode 46 of a couple is formed in the both ends of the GMR film 42 through the shunt layer 45 which consists of Au etc. Thus, MRAM40 is constituted.

[0055]

[Example] Next, the concrete example of this invention is described.

[0056] By the spatter, they are the amorphous CoNbZr alloy film of 10nm of thickness, and thickness as a magnetic substrate layer 12 first on an example 1 thermal-oxidation Si substrate. The 2nm NiFe alloy film was formed in order. Here, a NiFe alloy film serves as the metal buffer layer 4.

[0057] After forming the above-mentioned NiFe alloy film, the front face was once exposed to atmospheric air, and the passive state film was formed as an atomic diffusion barrier layer on the NiFe alloy film. In addition, average thickness is abbreviation when the condition of this passive state film was investigated in the cross section TEM. It was 1nm and the formation condition was island-like discontinuity.

[0058] Next, it is thickness as a ferromagnetic layer 11 on the NiFe alloy film in which the passive state film was formed on the front face. A 3nm Co90Fe10 alloy film, It is thickness as a nonmagnetic interlayer 3. It is thickness as 3nm Cu film and the 2nd magnetic layer 2. It is thickness as the IrMn alloy film of 10nm of thickness, and a protective layer as a 3nm Co90Fe10 alloy film and an antiferromagnetism layer 6. The laminating of the 5nm Ta film was carried out to order, and the spin bulb cascade screen 13 (7) was produced.

[0059] On the other hand, the spin bulb cascade screen was produced like the above-mentioned example 1 except forming all layers continuously within a vacuum chamber, without exposing the front face to atmospheric air as an example 1 of a comparison with this invention, after forming a NiFe alloy film. The atomic diffusion barrier layer is not formed in the interface of a NiFe alloy film and a Co90Fe10 alloy film in the spin bulb cascade screen of this example 1 of a comparison.

[0060] After carrying out patterning of each spin bulb cascade screen by the above-mentioned example 1 and the above-mentioned example 1 of a comparison, annealing treatment was carried out by 523K, respectively. Thus, MR rate of change of each obtained MR element was measured. MR rate of change It reaches after annealing of 2 hours, annealing of 10 hours, and annealing of 50 hours. It measured after annealing of 100 hours, respectively, and the thermal stability of MR element by the example and MR element by the example of a comparison was compared from these measurement results. The measurement result of MR rate of change after each annealing time amount progress is shown

in a table 1.
[0061]
[A table 1]

	MR変化率(%)				
アニール時間	0時間 (as depo)	2時間	10時間	50時間	100時間
実施例1	6.2%	8.0%	8.0%	8.0%	8.0%
比較例1	6.9%	6.1%	5.9%	5.4%	4.9%

As shown in a table 1, although MR rate of change immediately after membrane formation is comparatively as good as 6.9%, in the example 1 of a comparison which carries out package membrane formation and does not form the atomic diffusion barrier layer in a NiFe alloy film / Co90Fe10 alloy film interface, MR rate of change is decreasing rapidly after annealing of 2 hours. And after annealing which is 100 hours, MR rate of change decreased to 4.9% that MR rate of change continues decreasing in connection with the annealing passage of time also after that. Since the barrier layer which suppresses atomic diffusion does not exist in a NiFe alloy film / Co90Fe10 alloy film interface, the atomic counter diffusion between layers advances by annealing, and this is considered that MR rate of change decreased by this. Thus, the thermal stability (thermal resistance) of MR element of the example 1 of a comparison was low.
[0062] In the example 1 which once exposed to atmospheric air after formation of a NiFe alloy film, and, on the other hand, formed the atomic diffusion barrier layer in the NiFe alloy film / Co90Fe10 alloy film interface, although the property immediately after membrane formation was lower than the example 1 of a comparison, after annealing of 2 hours, MR rate of change rose to 8.0%. This While the crystallinity of each class etc. improves by the annealing treatment of 2 hours, it is thought that it is because atomic diffusion of a NiFe alloy film / Co90Fe10 alloy film interface was suppressed according to the atomic diffusion barrier layer. Furthermore, even if it performs prolonged annealing, as for MR rate of change, it turns out that it does not decrease from 8.0% but atomic diffusion of a NiFe alloy film / Co90Fe10 alloy film interface is suppressed. Thus, MR element of an example 1 was what is excellent in thermal stability (thermal resistance).
[0063] They are the amorphous CoNbZr alloy film of 10nm of thickness, and thickness as a magnetic substrate layer 12 first by the plasma spatter method on an example 2 thermal-oxidation Si substrate. The 2nm NiFe alloy film was formed in order. Here, a NiFe alloy film serves as the metal buffer layer 4.
[0064] After forming the above-mentioned NiFe alloy film, the plasma is once erased, and it is oxygen in a vacuum chamber. The argon gas mixed 20% was introduced and the oxide film was formed in the front face of a NiFe alloy film as an atomic diffusion barrier layer. Under the present circumstances, various thickness of a scaling film was changed by controlling the introductory pressure and time amount of mixed gas of oxygen and an argon. The average thickness of the obtained scaling film is as being shown in the following table 2. In addition, the example 2 of a comparison in a table makes thickness of a scaling film out of range [this invention].
[0065]
[A table 2]

	試料 No	表面酸化膜の平均厚さ (nm)
実施例2	1	0.3
	2	0.5
	3	1.0
比較例2	4	3.0

In addition, the thickness of the scaling film shown in a table 2 is not average thickness, and the oxide film of the thickness is not necessarily formed in homogeneity. For this reason, the average thickness of a scaling film Example 2 which is 0.3nm By the sample of No1, many pinholes existed in the scaling film comparatively.
[0066] Next, it is thickness as a ferromagnetic layer 11 on each NiFe alloy film in which the scaling film was formed, respectively. A 3nm Co90Fe10 alloy film, It is thickness as a nonmagnetic interlayer 3. It is thickness as 3nm Cu film

and the 2nd magnetic layer 2. It is thickness as a 2nm Co90Fe10 alloy film and an antiferromagnetism layer 6. It is thickness as a 8nm IrMn alloy film and a protective layer. The laminating of the 5nm Ta film is carried out to order. The spin bulb cascade screen 13 (7) was produced, respectively.

[0067] After carrying out patterning of each spin bulb cascade screen by the above-mentioned example 2 and the above-mentioned example 2 of a comparison, it is 523K, respectively. Annealing treatment was carried out for 2 hours. Thus, MR rate of change of each obtained MR element is reached immediately after membrane formation. It measured after annealing of 2 hours, respectively. These measurement results are shown in a table 3.

[0068]

[A table 3]

	試料 No	表面酸化膜の平均厚さ(nm)	MR変化率(%)	
			成膜直後	2時間アニール後
実施例2	1	0.3	5.8	6.2
	2	0.5	6.1	7.0
	3	1.0	6.0	8.2
比較例2	4	3.0	5.0	5.2

Each MR element by the example 2 is all. MR rate of change was rising after annealing of 2 hours, and the effect of the atomic diffusion barrier layer which consists of a scaling film was checked. However, although lifting of MR rate of change is presumed to be that to which atomic counter diffusion had happened a little not much greatly by the sample with the thin thickness of a scaling film, it is the thickness of a scaling film. Good MR rate of change is acquired by the sample set to 1nm.

[0069] On the other hand, although MR rate of change is rising a little after MR element by the example 2 of a comparison, and annealing of 2 hours, since MR rate of change of the beginning (immediately after membrane formation) is small, MR rate of change sufficient as a result is not acquired. Since this thickened thickness of a scaling film too much, it is considered because the effect of a magnetic substrate layer and a metal buffer layer is no longer acquired. since [moreover,] a fcc stacking tendency was not fully acquired but magnetic association with a magnetic substrate layer has run out further -- soft magnetic characteristics -- deteriorating -- coercive force Hc 3Oe it was .

[0070]

[Effect of the Invention] As explained above, according to this invention, it becomes possible to offer the magneto-resistive effect element which was highly efficient and was excellent in thermal stability from the ability of the thermal diffusion between a metal buffer layer, a magnetic layer or a magnetic substrate layer, and a ferromagnetic layer to be controlled.

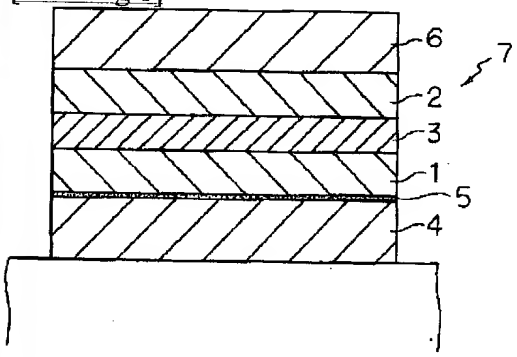
[Translation done.]

* NOTICES *

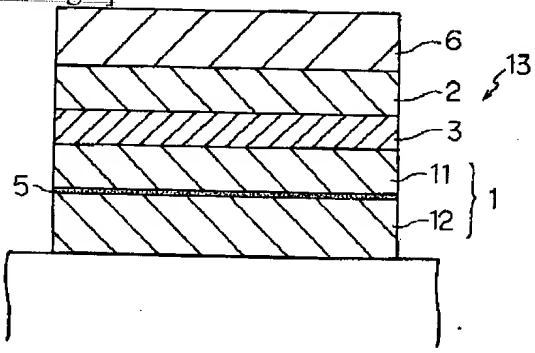
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

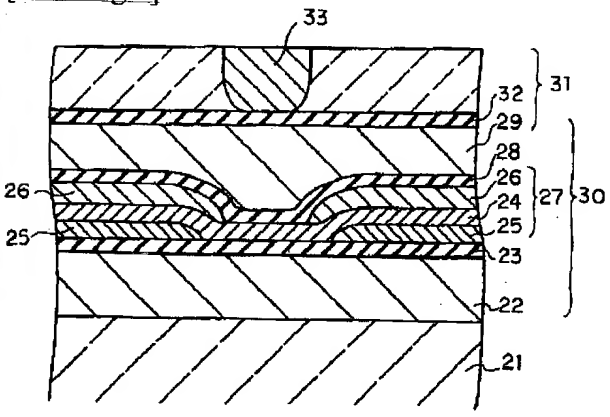
[Drawing 1]



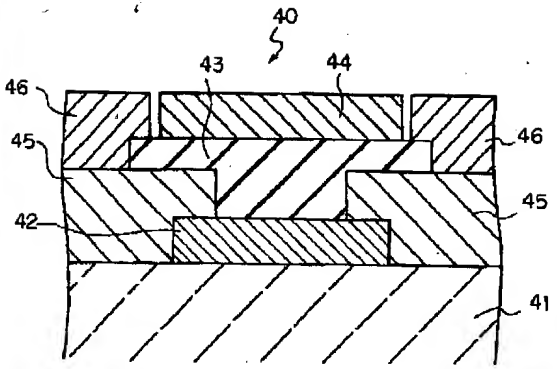
[Drawing 2]



[Drawing 3]



[Drawing 4]



[Translation done.]

* NOTICES *

CORRECTION OR AMENDMENT

[Official Gazette Type] Printing of amendment by convention of 2 of Article 17 of patent law
[A category partition] The 2nd partition of the 7th category
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H01L 43/08
G11B 5/39
H01F 10/08

[FI]

H01L 43/08 Z
G11B 5/39
H01F 10/08

[Procedure amendment]
[Filing Date] July 7, Heisei 12 (2000. 7.7)
[Procedure amendment 1]
[Document to be Amended] Description
[Item(s) to be Amended] The name of invention
[Method of Amendment] Modification
[Proposed Amendment]
[Title of the Invention] The magnetic head and a magnetic recorder and reproducing device using a magneto-resistive effect element and it
[Procedure amendment 2]
[Document to be Amended] Description
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 1st magnetic layer formed on a metal buffer layer, the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer,
A magneto-resistive effect element to which average thickness is characterized by establishing an atomic diffusion barrier layer 2nm or less at an interface of said metal buffer layer and 1st magnetic layer.
[Claim 2] In a magneto-resistive effect element possessing a spin bulb film which has the nonmagnetic middle class stationed between the 1st magnetic layer which consists of a cascade screen of a magnetic substrate layer and a ferromagnetic layer, the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer,

A magneto-resistive effect element to which average thickness is characterized by establishing an atomic diffusion barrier layer 2nm or less at an interface of said magnetic substrate layer and ferromagnetic layer.

[Claim 3] In a magneto-resistive effect element according to claim 1 or 2,
Said atomic diffusion barrier layer is a magneto-resistive effect element characterized by having 0.3nm or more average thickness of 2nm or less.

[Claim 4] In a magneto-resistive effect element according to claim 1 or 3,
It is the magneto-resistive effect element characterized by for said metal buffer layer consisting of a metallic material which has the fcc crystal structure, and said 1st magnetic layer consisting of a ferromagnetic containing Co.

[Claim 5] In a magneto-resistive effect element according to claim 2 or 3,
It is the magneto-resistive effect element characterized by for said magnetic substrate layer consisting of a metallic material which has the fcc crystal structure, and said ferromagnetic layer consisting of a ferromagnetic containing Co.

[Claim 6] In a magneto-resistive effect element of claim 1 thru/or claim 5 given in any 1 term,
Said atomic diffusion barrier layer is a magneto-resistive effect element characterized by using as a principal component at least one sort chosen from an oxide, a nitride, carbide, a boride, and a fluoride.

[Claim 7] In a magneto-resistive effect element of claim 1 thru/or claim 6 given in any 1 term,
A magneto-resistive effect element characterized by forming a pinhole in said atomic diffusion barrier layer.

[Claim 8] In a magneto-resistive effect element of claim 1 thru/or claim 6 given in any 1 term,
Said atomic diffusion barrier layer is a magneto-resistive effect element characterized by being formed in the condition of having existed in the shape of an island.

[Claim 9] In a magneto-resistive effect element of claim 1 thru/or claim 8 given in any 1 term,
Said atomic diffusion barrier layer is a magneto-resistive effect element characterized by consisting of a ferromagnetic or the antiferromagnetic substance.

[Claim 10] In a magneto-resistive effect element of claim 1 thru/or claim 8 given in any 1 term,
Said atomic diffusion barrier layer is a magneto-resistive effect element characterized by being constituted with a metallic oxide.

[Claim 11] A metal layer,
The 1st magnetic layer arranged so that said metal layer may be touched,
With a nonmagnetic interlayer formed on said 1st magnetic layer
The 2nd ferromagnetic layer formed on said nonmagnetic interlayer so that said nonmagnetic interlayer might intervene between said 1st magnetic layer,
A magneto-resistive effect element characterized by providing a volume phase which uses as a principal component at least one sort which is arranged between said metal layer and said 1st magnetic layer, and is chosen from NiO, CoO, MnxN, FexN, and a spinel ferrite.

[Claim 12] A metal layer,
The 1st magnetic layer arranged so that said metal layer may be touched,
With a nonmagnetic interlayer formed on said 1st magnetic layer
The 2nd ferromagnetic layer formed on said nonmagnetic interlayer so that said nonmagnetic interlayer might intervene between said 1st magnetic layer,
A magneto-resistive effect element characterized by providing a volume phase which uses as a principal component at least one sort which is arranged between said metal layer and said 1st magnetic layer, and is chosen from an oxide, a nitride, carbide, a boride, and a fluoride.

[Claim 13] A metal layer,
The 1st magnetic layer arranged so that said metal layer may be touched,
With a nonmagnetic interlayer formed on said 1st magnetic layer
The 2nd ferromagnetic layer formed on said nonmagnetic interlayer so that said nonmagnetic interlayer might intervene between said 1st magnetic layer,
A magneto-resistive effect element characterized by providing a volume phase which consists of a crystalline substance material which uses as a principal component at least one sort which is arranged between said metal layer and said 1st magnetic layer, and is chosen from an oxide, a nitride, carbide, a boride, and a fluoride.

[Claim 14] A metal layer,
The 1st magnetic layer arranged so that said metal layer may be touched,
With a nonmagnetic interlayer formed on said 1st magnetic layer
The 2nd ferromagnetic layer formed on said nonmagnetic interlayer so that said nonmagnetic interlayer might intervene between said 1st magnetic layer,

It is arranged between said metal layer and said 1st magnetic layer, and while using as a principal component at least one sort chosen from an oxide, a nitride, carbide, a boride, and a fluoride, a volume phase which has a pinhole is provided,
Average size of said pinhole is a magneto-resistive effect element characterized by being less than [distance between adjoining pinholes, an EQC, or it].
[Claim 15] A metal layer which consists of an alloy containing Ta, Ti, Cr, Cu, Au, Ag, and these,
The 1st magnetic layer arranged so that said metal layer may be touched,
With a nonmagnetic interlayer formed on said 1st magnetic layer
The 2nd ferromagnetic layer formed on said nonmagnetic interlayer so that said nonmagnetic interlayer might intervene between said 1st magnetic layer,
A magneto-resistive effect element characterized by providing a volume phase which uses as a principal component at least one sort which is arranged between said metal layer and said 1st magnetic layer, and is chosen from an oxide, a nitride, carbide, a boride, and a fluoride.
[Claim 16] The magnetic head characterized by providing a magneto-resistive effect element of claim 1 thru/or claim 15 given in any 1 term.
[Claim 17] The magnetic-recording reproducing head characterized by providing the playback magnetic head which has the magnetic head according to claim 16, and the record magnetic head.
[Claim 18] A magnetic recorder and reproducing device characterized by providing the magnetic-recording reproducing head according to claim 17 and magnetic-recording data medium.
[Procedure amendment 3]
[Document to be Amended] Description
[Item(s) to be Amended] 0001
[Method of Amendment] Modification
[Proposed Amendment]
[0001]
[The technical field to which invention belongs] This invention relates to the magnetic head and the magnetic recorder and reproducing device using the magneto-resistive effect element and it which used the spin bulb film.
[Procedure amendment 4]
[Document to be Amended] Description
[Item(s) to be Amended] 0009
[Method of Amendment] Modification
[Proposed Amendment]
[0009] This invention was made in order to cope with such a technical problem, and it aims at offering the magnetic head and the magnetic recorder and reproducing device using a magneto-resistive effect element and it of the high performance excellent in thermal stability by controlling thermal diffusion.
[Procedure amendment 5]
[Document to be Amended] Description
[Item(s) to be Amended] 0011
[Method of Amendment] Modification
[Proposed Amendment]
[0011] The 1st magnetic layer which the 1st magneto-resistive effect element becomes from the ferromagnetic containing Co further formed on the metal buffer layer which has a fcc crystal structure, In the magneto-resistive effect element possessing the spin bulb film which has the nonmagnetic middle class stationed between the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer It is characterized by establishing the atomic diffusion barrier layer which uses as a principal component at least one sort chosen as the interface of said metal buffer layer and 1st magnetic layer from an oxide, a nitride, carbide, a boride, and a fluoride.
[Procedure amendment 6]
[Document to be Amended] Description
[Item(s) to be Amended] 0012
[Method of Amendment] Modification
[Proposed Amendment]
[0012] Moreover, the 2nd magneto-resistive effect element in this invention The 1st magnetic layer which consists of a cascade screen of a magnetic substrate layer and a ferromagnetic layer as indicated to claim 2, In the magneto-resistive effect element possessing the spin bulb film which has the nonmagnetic middle class stationed between the 2nd

magnetic layer, and said 1st magnetic layer and 2nd magnetic layer Average thickness is characterized by establishing the atomic diffusion barrier layer 2nm or less at the interface of said magnetic substrate layer and ferromagnetic layer.

[Procedure amendment 7]

[Document to be Amended] Description

[Item(s) to be Amended] 0013

[Method of Amendment] Modification

[Proposed Amendment]

[0013] The 1st magnetic layer which the 2nd magneto-resistive effect element becomes from the cascade screen of a magnetic substrate layer and the ferromagnetic layer containing Co further, In the magneto-resistive effect element possessing the spin bulb film which has the nonmagnetic middle class stationed between the 2nd magnetic layer, and said 1st magnetic layer and 2nd magnetic layer It is characterized by establishing the atomic diffusion barrier layer which uses as a principal component at least one sort chosen as the interface of said magnetic substrate layer and ferromagnetic layer from an oxide, a nitride, carbide, a boride, and a fluoride. Furthermore, the magnetic head of this invention is characterized by providing the magneto-resistive effect element of above-mentioned this invention. The magnetic-recording reproducing head of this invention is characterized by providing the playback magnetic head which has the magnetic head of this invention, and the record magnetic head. The magnetic recorder and reproducing device of this invention is characterized by providing the magnetic-recording reproducing head and magnetic-recording data medium of this invention.

[Translation done.]